

KEMEX

CHEMICAL EXPERIMENTS



INSTRUCTIONS

FOR

No. 1 OUTFIT

MECCANO LIMITED

LIVERPOOL ENGLAND

PRICE - NINEPENCE

MECCANO



KEMEX

Reg.
538304



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CHEMICAL EXPERIMENTS

The Kemex Outfits have been introduced to provide apparatus, materials and instructions for carrying out a series of fascinating experiments in which the secrets of the wonderful science of chemistry are revealed.

This No. 1 Outfit contains the necessary apparatus and chemicals to perform 130 attractive experiments. In addition to making gases, preparing crystals and testing for acids and alkalies, there are fascinating amusements with a chemical garden that actually grows, and with mysterious inks that remain invisible until their secret is known.

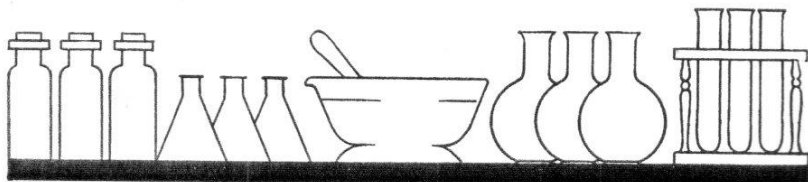
The No. 2 Outfit opens up a much wider range. Its contents enable all the No. 1 Outfit experiments to be performed. In addition, wool and silk can be dyed,

soap can be made, and metals can be smelted from their compounds. With this Outfit 250 interesting experiments can be carried out.

The No. 3 Outfit completes the Kemex scheme, and with it from 350 to 400 experiments can be made. It covers the whole range of the No. 1 and No. 2 Outfits, and has additional apparatus and materials for a further series of experiments, showing how chemistry is applied in the home and in the factory.

To get the greatest fun from your Kemex Outfit you should read the "*Meccano Magazine*," in which special articles link up with the Outfits and describe new and interesting experiments in all branches of chemistry.

Kemex Outfits for Chemical Fun!



Kemex Chemical Experiments

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1. THE BEGINNINGS OF CHEMISTRY

The earliest chemical experiments date back to prehistoric times, and were concerned with the crude operations by which primitive Man produced metals from their ores. The first metals to be noticed by Man were probably gold, silver and copper, which would attract his attention by reason of their bright colour. He would soon find that gold and silver were of little practical use on account of their softness, but that copper could be made into satisfactory weapons, tools and domestic utensils of many kinds. We do not know how or when the art of smelting copper was discovered, but it has been suggested that it came about in the later stages of what is known as the Stone Age, through the accidental use of copper ore stones in the fire-pits built for cooking purposes. Later came the discovery that copper could be hardened by the addition of tin, thus producing the alloy bronze. Possibly this discovery was made accidentally during the smelting of copper ores along with which were ores containing tin.

It is probable that copper and bronze were in use as far back as 10,000 years ago. Certain Egyptian relics of these metals are believed to date back 7,000 years, and there is evidence that copper tools were made in Ireland some 2,500 years B.C., while in Great Britain bronze is thought to have been the chief metal in use until about 1,000 B.C., when iron began to displace it.

Experiment in Copper Smelting

In view of the great antiquity of copper smelting it will be interesting to commence our chemical experiments with one of this nature. For this we require a piece of wood about 4 in. in length and about twice the thickness of a match. Hold the end in the flame of the Spirit Lamp (Part No. K22) until the wood begins to char, and then rub it with a large crystal of washing soda. Some of the soda is absorbed, and by repeating the action the end of the stick becomes transformed into a piece of charcoal thoroughly soaked in soda.

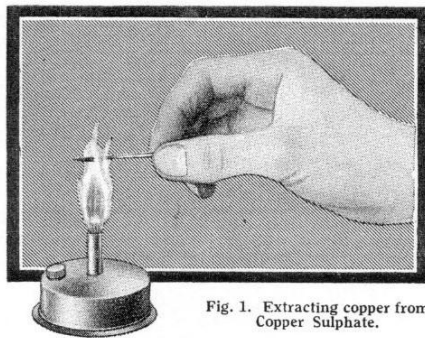


Fig. 1. Extracting copper from Copper Sulphate.

Crush a few small crystals of Copper Sulphate (No. K108); place as much as possible of the substance on the charred end of the stick, and hold this in the flame (Fig. 1).

The blue powder becomes white, and further colour changes take place as the match continues to burn, the mass becoming black with a reddish tint in places. The soda prevents the wood from burning away quickly, and also acts as a "flux." A flux is a substance used to help in separating metals from the other constituents of their ores; in this case the soda assists the materials on the wood to become liquid.

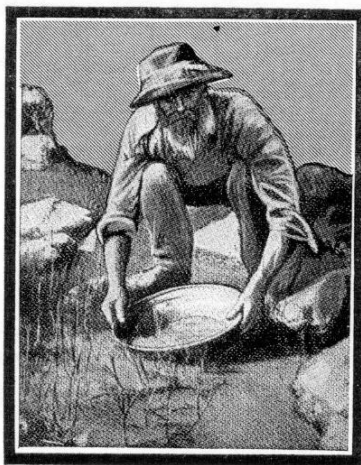


Fig. 2. A prospector at work, panning gold-bearing gravel.

Stop the heating before the charred end of the wood burns away or falls off, and break the end off into a dish or small saucer half filled with water. With the point of a penknife, or the end of the Glass Rod

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(Part No. K16), crush the charred end and stir it into the water, and then give the dish a circular movement in order to wash the remains. Add more water and continue the movement, tilting the dish slightly so that the water swirls out over the edge, a process similar to that used by gold prospectors when washing gold-bearing gravel in a pan (Fig. 2). The light charcoal is washed away, the remaining soda is dissolved, and finally reddish-brown particles are left at the bottom of the dish. These particles are flakes of copper smelted out of the Copper Sulphate. Most of the water remaining on the copper may be removed by blotting paper, and the drying completed by leaving the dish in a warm place for a few minutes.

Metals that are Magnetic

Two other metals that may be extracted in a similar manner from their compounds are iron and cobalt. In these cases the experiments must be carried out with the Iron Alum (No. K11), and Cobalt Chloride (No. K105)

contained in the Outfit. The metals are obtained in the form of dark grey powders. There is no difficulty in recognising them, however, for they are magnetic, and in each experiment the dark grains left in the porcelain dish adhere to a magnet dipped into them.

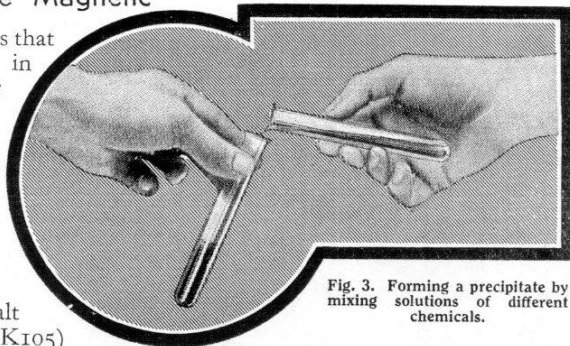


Fig. 3. Forming a precipitate by mixing solutions of different chemicals.

that later became prominent. The most famous chemists of the Middle Ages were the Arabs, who called the science *al kimia*, an Arabic name from which the word "alchemy" was derived. Unfortunately many of the later alchemists spent their time in searching for the "Philosopher's Stone," an imaginary stone or mineral compound by means of which common metals could be changed into gold, and with them the science fell into disrepute.

Alchemy practically came to an end in the 16th century when modern chemistry began with Robert Boyle (1627-1691), who is known as the "Father of Chemistry." Boyle was a great experimental chemist, but is chiefly famous for his suggestion that all things were built up of a certain number of elements, or simple substances that cannot themselves be split up. The idea of elements was not new, for the ancient Greeks believed that all things were built up from fire, air, water and earth in varying proportions. To-day 91 chemical elements are recognised.

Compounds built up from Elements

Substances that are not elements are known as compounds. They are built up from elements by combining these in various proportions, but they must be formed by what is known as a chemical change, in which is produced a substance that is entirely different from its components.

The two following experiments will make clear the distinction between mere mixing and real chemical action. A Scoop (Part No. K36) is included in the Outfit for roughly

2. ALCHEMY AND CHEMICAL CHANGES

In addition to smelting operations for producing metals, the ancients carried out experiments with a variety of chemicals, including salt, potash and soda. Many important investigations were performed by the chemists of ancient Egypt, a land in which metals were used at a very early period, and by those of Greece, Rome and other countries

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measuring the quantities of chemicals required in experiments, and in this Manual one scoopful will be described as one measure.

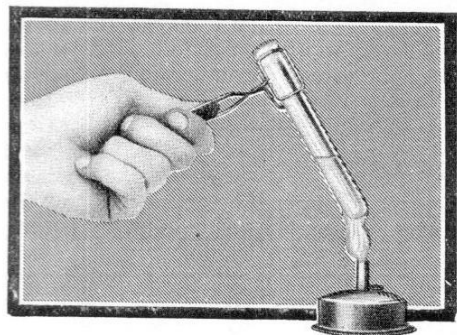


Fig. 4. Displacing copper from Copper Sulphate by means of Zinc.

Add two measures of common salt to a Test Tube (Part No. K1) half full of water. Close the end of the test tube with the thumb and invert the tube rapidly several times so as to shake the salt and water together. The salt disappears, but its presence in the liquid may be shown by tasting it. The salt has not combined with the water to form a new substance. It has only dissolved to form a solution, and the change is not of the kind we have described as chemical.

Now mix two measures each of Sulphur (No. K131) and Iron Filings (No. K112) on the lid of a small tin. The particles of iron may readily be seen in this mixture, and may be extracted from it by means of a magnet. Thus no chemical change has taken place, for no new substance has been formed.

Heat the mixture by holding the tin in a pair of tongs over a fire, or the flame of the spirit lamp. Some of the sulphur burns with a blue flame, but a black substance is formed in the tin. When this substance is cool, break it up and place part of it in a test

tube. Add one measure of Sodium Bisulphate (No. K125) and cover with water. Bubbles are formed in the liquid, and a gas with the unpleasant smell of bad eggs is produced. This gas cannot be obtained by the action of Sodium Bisulphate on either Iron Filings or Sulphur. A new substance therefore has been formed, and the change has been chemical.

Burning of Magnesium

The burning of magnesium is another chemical change that is brought about by heating. Cut a piece of Magnesium Ribbon (No. K116) an inch in length, and hold one end of it in a flame by means of the Test Tube Holder (Part No. K4), or a pair of pliers or small tongs. The metal burns and a white ash that is a new substance is formed.

Many interesting chemical changes take place in solution in water. Dissolve one measure of Cobalt Chloride (No. K105) in a test tube one-third full of water, and add to it a solution of washing soda made by dissolving a few crystals in a test tube containing water to a depth of 1 in. A light blue solid is formed in the liquid (Fig. 3).

A solid formed in this manner is called a precipitate, for it is precipitated, or thrown out of the liquid. In this case the solid is cobalt carbonate, an interchange taking place that gives also sodium nitrate, which is soluble in water and remains in solution.

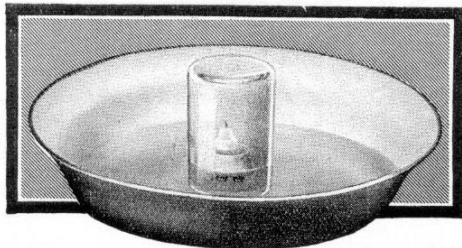


Fig. 5. Candle burning in a limited volume of air.

In other interesting examples of chemical change, one metal may be made to displace another. Dissolve two measures of Copper Sulphate (No. K108) in a test tube half full of water. Pour half of the solution into a second test tube, and dip in it the blade of your penknife, after cleaning the steel with emery paper. A reddish-brown coating is formed on the steel. This is copper, displaced from the

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solution of the chemical containing it, a little iron being dissolved in its stead. To the remainder of the Copper Sulphate solution add three small pieces of Granulated Zinc (No. K134) and heat, holding the test tube in the test tube holder with its lower end in the flame, and its mouth pointing away from the face (Fig. 4). *This precaution should always be taken when heating a liquid in a test tube.* The Zinc acts on the hot Copper Sulphate solution and a reddish-brown powder is formed. This is copper, displaced by the zinc in the same manner as by the iron in the previous experiment. The solution becomes colourless and now contains zinc sulphate instead of Copper Sulphate.

3. BURNING AND BREATHING

In one of the experiments already made we showed that the burning of magnesium is a chemical change. The burning of any combustible must be a change of this kind, for a new substance always is produced, and many striking experiments reveal the mysteries of burning and also of breathing.

For the first experiment fix a short piece of candle on a cork, and float this on water about 2 in. in depth in a shallow bowl or basin, screwing Meccano bolts into the underside of the cork if necessary in order to make it float upright. Light the candle and cover it with an inverted glass jar placed with its mouth at the bottom of the bowl, and of course under the surface of the water (Fig. 5).

The flame soon becomes paler and at last dies out altogether, and when the jar has

become cold the level of the water in it is higher than at the beginning of the experiment. Thus some of the air has disappeared, although its escape was cut off. With the jar still upside down in the bowl extract the cork and candle. Then close the mouth of the jar with a sheet of paper or thin cardboard, and lift it out, placing it upright on the table. Test the remaining air by putting the lighted end of a taper in it, pulling the paper cover aside for this purpose (Fig. 6). The flame is immediately extinguished.

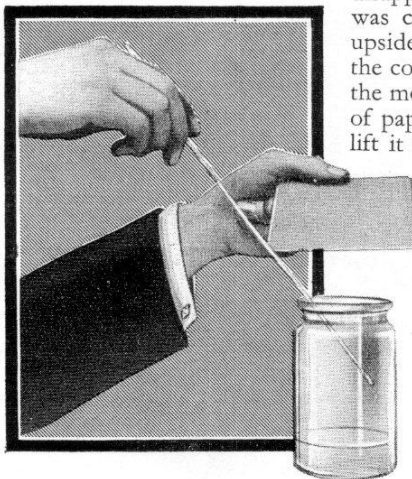


Fig. 6. Testing the gas left after a candle has burned.

This experiment shows that air contains two gases, one of which is used up when the candle burns. The proportion removed in this manner is about one-fifth, and the remaining four-fifths is of no use for burning. The first of these gases is oxygen, formerly known as "fire air" because it is necessary in burning, and the second is called nitrogen. Both are elements.

The experiment may be repeated with sulphur instead of a candle. This substance is best placed on a small tin lid resting on the cork, and lighted by means of a match.

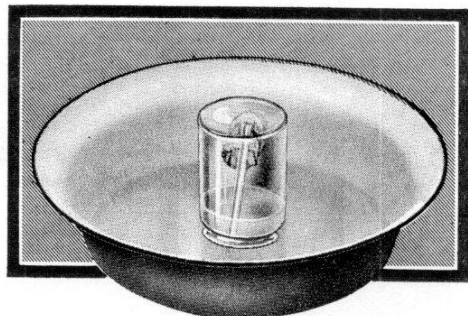


Fig. 7. Showing that the rusting of iron is slow burning.

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Rusting is Slow Burning

Now let us try a similar experiment with a metal that does not burn, but apparently undergoes a change of another kind when exposed to the air. This is iron, which rusts readily, especially in moist air, and the formation of the reddish brown material clearly is a chemical change. Collect a number of small fragments of iron, such as tacks and small nuts and bolts. Wrap these in a piece of muslin and suspend them from the top of the glass rod inside a jar standing upside down in water (Fig. 7). Leave the jar undisturbed for a day or two and then examine the contents of the muslin bag; they will be found to have acquired a coating of rust. As the iron rusts the level of the water in the jar rises, showing that something is taken out of the air. No matter how much iron is enclosed in the muslin bag, however, or how long it stays in the jar, the proportion of air removed is never greater than one-fifth, and the gas remaining in the jar will not allow a taper to burn in it. It is nitrogen, in fact, and the iron in rusting has removed the oxygen.

This experiment shows that rusting is a similar chemical change to burning, the only difference being that rusting takes place much more slowly than burning and is not accompanied by a flame. Oxygen is necessary for both, and a candle will not burn, nor will iron rust, if this gas is absent.

These experiments give the solution to the problem of burning and rusting. What happens is that the substance concerned unites with the oxygen of the air, and for this reason the new compound formed is said to be an oxide. Thus iron rust is

oxide of iron produced by the union of iron and oxygen; the white ash formed when magnesium burns is magnesium oxide.

Detecting Invisible Gases

It may be asked why a candle and sulphur do not form oxides of this kind when they burn in the air, for in burning they seem to disappear. The answer is that the oxides formed in these cases are invisible because they are colourless gases. That formed when Sulphur burns is sulphur dioxide and may be detected by its choking smell. Carbon dioxide is formed when a candle burns, for carbon is the chief element present in the material of the candle. This gas has no smell, but is easily recognised, although colourless and invisible, as explained in the following experiment.

For this purpose lime water is required, and this is made by putting one measure of Calcium Oxide (No. K103) in a test tube containing water to a depth of about 2 in. Shake the test tube in order to dissolve as much lime as possible and allow the remainder to settle in the bottom of the tube. The clear liquid is a

solution of lime and is usually known as lime water. Pour it carefully into a second test tube.

Place the cork with the piece of candle on it used in a previous experiment on the bottom of the jar and cover this loosely with a piece of card. When the candle is lighted it burns for some time, but eventually is extinguished. Then lift out the cork and candle and pour part of the lime water into the jar. On shaking, the lime water becomes milky in appearance. This is a test for carbon dioxide and the effect of the gas in the jar on the lime water is a proof that the burning



Fig. 8. Breathing through lime water shows that breathing is a similar chemical change to burning.

of the candle has resulted in the formation of this gas.

It is interesting to know that chemical changes similar to the burning of a candle take place within our bodies. We are built up of very complex chemical substances containing carbon, and the oxygen of the air taken into our lungs when we breathe comes in contact with carbon compounds in the blood, which circulates through the lungs for this purpose. A gentle burning process occurs, with the formation of carbon dioxide; and the air we breathe out contains this gas in addition to nitrogen and a proportion of oxygen that has not been used. In order to prove this, gently bubble the breath through a glass tube dipping below the surface of the lime water remaining in the test tube (Fig. 8). The liquid turns milky almost immediately, showing that carbon dioxide is present. The heat of the slow burning that produces this gas in the lungs helps to keep up bodily temperature.

4. OXYGEN—THE ELEMENT THAT SUPPORTS LIFE

Clearly oxygen is a very important gas, and it is interesting to prepare it in the pure

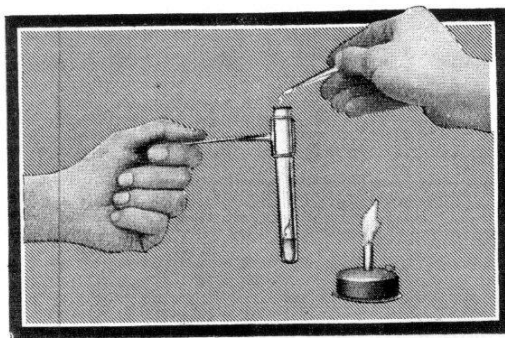
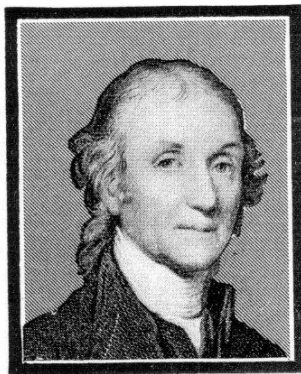


Fig. 9. Dropping Sulphur into melted Potassium Nitrate, in which it takes fire.



Joseph Priestley (1733-1804)

state. It is not easy to extract it directly from the air, but fortunately it may be obtained by heating certain chemicals containing it. One of these is mercury oxide, and this substance was used by Dr. Joseph Priestley, the famous English chemist, when he discovered the gas in 1774.

Another chemical we may use as a source of oxygen is nitre or saltpetre, known to the chemist as Potassium Nitrate, and an interesting experiment will show the presence of this element in it. Heat three measures of Potassium Nitrate (No. K124) in a small test tube until it melts and begins to bubble. Then remove the tube from the flame, and holding it almost vertically, and with the mouth pointing away from you, drop into it half a measure of Sulphur (No. K131). This takes fire and burns as it floats on the liquid in the tube, and the flame is more brilliant than in the air because it is fed with pure concentrated oxygen from the melted Potassium Nitrate (Fig. 9).

Potassium Nitrate may be used for fire writing. Add a few drops of water to one measure of the chemical in a test tube and warm until it dissolves, holding the test tube by means of the test tube holder and pointing its mouth away from you. Use the solution as an invisible ink to write or draw on thin paper, marking the beginning with a pencilled cross and making all the strokes heavy and the writing or drawing continuous. Allow the paper to dry and touch the beginning of the writing with a red hot wire. A spark then travels slowly over the paper, tracing out the design or words, for the oxygen of the Potassium Nitrate causes the paper on this track to be easily burned.

A more convenient chemical from which to obtain oxygen is Potassium Chlorate (No. K122). Crush two measures of this to powder by means of a piece of hard wood

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and heat it in a small test tube. It melts, and on further heating, bubbles of oxygen rise to the surface.

In order to show that the gas produced is oxygen, put the glowing end of a half-burned chip of wood inside the tube. The wood will immediately burst into flame, for the glowing chip burns so furiously in the oxygen that the temperature rises to ignition point again. A glowing wood chip is an excellent means of testing for oxygen, and the wood spills sold by tobacconists are specially suitable for the purpose.

Making Fire Air

M a k i n g oxygen on a large scale and collecting it is one of the most interesting and attractive chemical

experiments. The gas is best prepared by heating a mixture of powdered Potassium Chlorate (No. K122) and Manganese Dioxide (No. K118), a black substance that has the remarkable power of assisting the oxygen to escape from Potassium Chlorate at a lower temperature than would be required in its absence. Crush the Potassium Chlorate that still remains in the Outfit and mix it with about one-quarter of the amount of Manganese Dioxide. Put the mixture in a test tube that has been thoroughly dried by keeping it for some time in a warm place.

Next, carefully work one end of the Double Angle Delivery Tube (Part No. K14) through one of the small Bored Corks (Part No. K19) with a screwing motion, a direct push being avoided as this may cause breakage. Fit the cork thus equipped into the test tube containing the oxygen mixture.

Means of collecting the gas must be provided. Test tubes may be used as gasholders, but small glass jars are more suitable, and the quantity of Potassium Chlorate gives sufficient oxygen to fill three vessels of the size of 1-lb. jam jars. A further requirement is a small bowl containing water to a depth of about 2 in.

The first jar to be used is filled with water and its mouth closed by pressing on it a piece of paper. It is then placed upside down

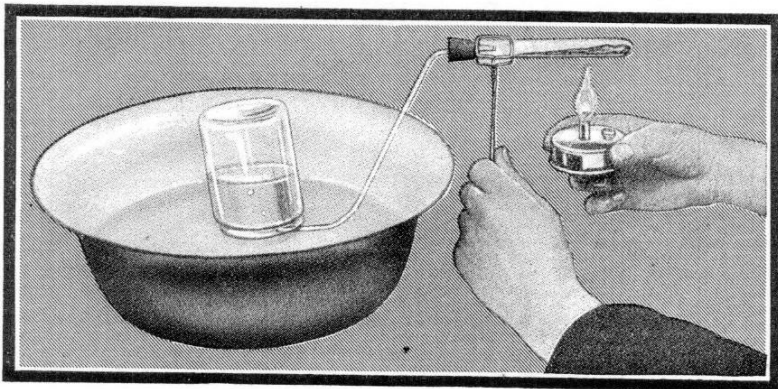


Fig. 10. Heating Potassium Chlorate and Manganese Dioxide and collecting the oxygen produced.

on the bottom of the bowl, and when the paper is removed the jar remains full of water, which is kept in position by the pressure of the atmosphere. In order to collect the gas to be given off in our experiment, all that is necessary is to hold the test tube by means of the test tube holder so that the open end of the delivery tube is under the mouth of the inverted jar, when the gas will bubble up and displace the water (Fig. 10).

Tap the tube gently until the mixture forms a layer along the lower side, leaving a clear passage above it for the gas; and commence to heat the mixture by moving the lighted spirit lamp backward and forward under the test tube. Bubbles of air driven out by the expansion due to heating first escape, but soon the stream becomes more rapid owing to the production of oxygen, and

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then the inverted jar must be placed above the end of the delivery tube. The spirit lamp may be put down for the brief time required for this, but a better plan is to call in the assistance of a friend, who may make himself useful by holding the jar in order to prevent it from toppling over, for it becomes unsteady when full of gas.

Stop the heating when all the water in the jar has been displaced by gas and immediately lift the delivery tube away in order to avoid the inrush of cold water that would follow the cooling of the gas inside, for this would spoil the experiment and perhaps break the test tube. Then slip a sheet of paper over the mouth of the jar of oxygen and lift this out, keeping the paper tightly pressed down. To prevent the subsequent escape of the gas invert a saucer over the wet paper. The second jar may then be placed ready for use as a gasholder and the experiment continued until all three jars are full of oxygen. Retain the mixture remaining in the test tube for use in a later experiment.

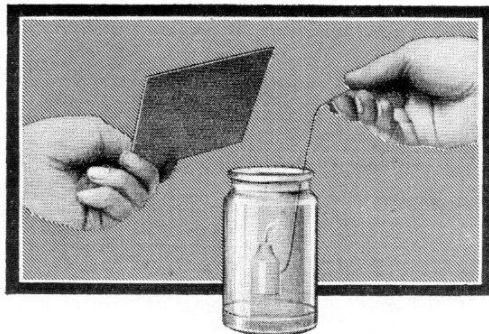


Fig. 11. A candle burns furiously and with a very brilliant flame in oxygen.

Furious Burning in Oxygen

Pour water into the first jar to a depth of about half an inch, and then lower into it a lighted piece of candle impaled on a wire (Fig. 11). The candle burns so furiously that the tallow melts rapidly in the great heat developed during the action.

The flame becomes duller and smokier when the oxygen in the jar has been used up. Remove the candle, cover the mouth of the jar, and shake in order to bring the water into contact with the gas remaining in it. Then place the vessel and its contents on one side for use in a later experiment.

Similar experiments with Sulphur (No. K131) and Magnesium Ribbon (No. K116) are equally striking. In each case the bottom of the jar should be covered with water. One measure of Sulphur is sufficient and may be burned in a tiny spoon made by suspending a piece of tin from a stout wire. Ignite the Sulphur by means of the flame of the spirit lamp and lower it into the second jar of oxygen, when its pale blue flame becomes far more brilliant. As in the case of the candle, shake the jar in order to dissolve the gas produced and keep the solution for a further experiment.

Hold a piece of Magnesium Ribbon about $1\frac{1}{2}$ in. in length in the test tube holder and ignite it before lowering into the third jar of oxygen. The Magnesium burns with a very brilliant flame in air, but the flame becomes dazzling in intensity the instant it is surrounded by pure oxygen. A white ash is formed and this may be allowed to drop into the water at the bottom of the jar, in which a little dissolves.

Chemical Detectives

Heat a measure of powdered Litmus (No. K114) in a test tube half filled with water. The liquid is allowed to cool and is then filtered in order to give a clear liquid.

The Funnel (Part No. K6) and a Filter Paper (Part No. K7) are required for filtering. Fold the circle of paper across its centre, and then again in order to form quadrants. The filter paper may then be opened out into the shape of a cone (Fig. 12), with three thicknesses of paper on one side and one thickness on the other. Fit the cone into the funnel, moisten the paper and press it into contact with the side. Then stand the funnel

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in a clean empty test tube and pour the liquid into it. Undissolved Litmus remains in the filter paper and a clear blue solution is collected in the test tube.

Pour a few drops of Litmus solution into the jars in which the candle and the sulphur were burned in oxygen. In the first jar the Litmus solution changes to a dull red and in the second to pink. The oxides of sulphur and carbon are said to be acid oxides, and the change of colour of the Litmus solution from blue to red is an indication of this.

It is not always convenient to use Litmus solution for tests of this kind and Litmus papers are sometimes employed instead. These are easily made from the solution already prepared by dipping into it strips of fine-grained blotting paper and allowing them to dry. A convenient size for the strips is 2 in. by $\frac{1}{4}$ in.

There are substances that have the power of bringing about the reverse change, and the red Litmus solution obtained by the addition of a few drops of acid to the blue solution we have prepared is once more turned blue when one of them is added to it. These substances are called alkalis. Red Litmus papers to be used as tests for alkalis may be prepared by dipping the blue ones in a solution formed by adding a few drops of vinegar, or dilute hydrochloric acid obtained from a chemist, to a test tube almost full of water.

Use Litmus papers to test solutions of common substances such as washing soda, baking soda, and ammonia, and of Sodium Bisulphate (No. KI25), Calcium Oxide (No. KI03) and other chemicals included in the Outfit.

Other interesting indicators include the

juices formed by crushing elderberries or dark coloured cherries, or by boiling shreds of fresh red cabbage with water. Test these also with substances known to be acids or alkalis.

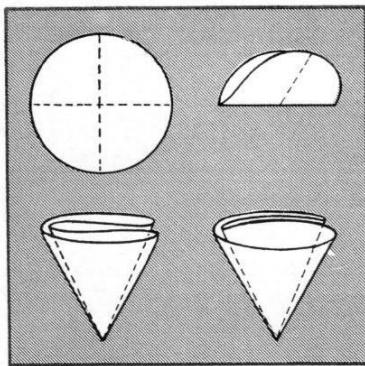


Fig. 12. How a filter paper is folded in order to make it fit the funnel.

Another chemical that can be used for detecting alkalis and acids is Logwood. Boil two measures of Logwood (No. KI15) in a test tube half filled with water for about five minutes and filter in order to obtain a clear solution. Divide the filtrate, or liquid that passes through the filter paper, into two portions. To one add a few small crystals of washing soda, and to the other a measure of Sodium Bisulphate (No. KI25). The washing soda is alkaline and turns the Logwood solution blue; the Sodium Bisulphate, which is acid, changes the colour from red to yellow.

5. HYDROGEN, LIGHTTEST OF GASES

Dissolve two measures of Sodium Bisulphate (No. KI25) in a test tube containing water to a depth of one inch and drop into the liquid a strip of Magnesium Ribbon (KI16) half an inch in length. There is a violent action, and a gas is given off that burns with a blue flame when the mouth of

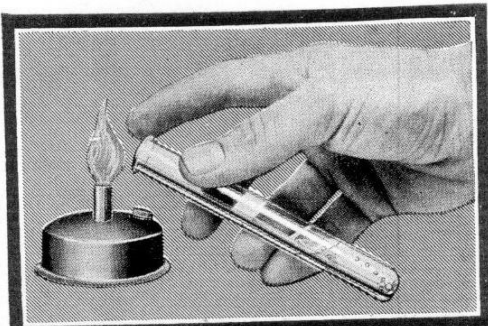


Fig. 13. Burning hydrogen at the mouth of the tube in which it is produced.

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the test tube is brought to the flame of the spirit lamp (Fig. 13). Similar results follow the use of Granulated Zinc (No. K134) or Iron Filings (No. K112) instead of Magnesium, but in these cases the action is less violent.

Hydrogen is colourless and has no smell. It is lighter than air, and may be collected in a test tube held above the mouth of the tube in which it is being produced. When collected in this manner the gas usually is mixed with a proportion of air, and there is a loud but harmless explosion when a light is applied to it.

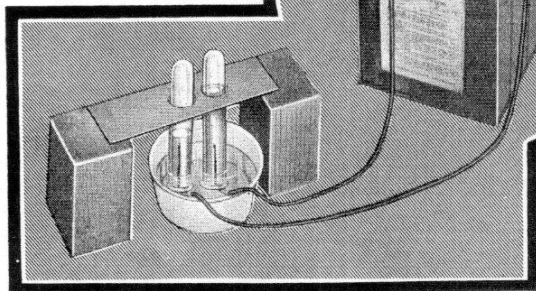
Inflammable Gas Extracted from Water

It is a little surprising to learn that hydrogen may be obtained by passing an electric current through water. For this purpose fit up the apparatus shown in Fig. 14. The small basin contains water to which sufficient Sodium Bisulphate (No. K125) to cover a shilling has been added. Fill each of two test tubes in turn with water, close it by means of the finger, and place it upside down

with its mouth under water in the basin.

When both test tubes are ready place over them a strip of thin wood or thick card pierced with two holes, in order to keep them in position, blocks of wood or other suitable objects being used for supporting the strip at the required height.

Fig. 14. Water is split into hydrogen and oxygen when an electric current is passed through it.



As a source of current either the Meccano Accumulator or a flashlamp battery may be employed, copper wires being attached to the positive and negative terminals. A stout piece of copper wire is attached to the negative lead, and the length of Nickel Chrome Wire (Part No. K39) contained in the Outfit is similarly attached to the positive lead, both being carefully turned upward into the test tubes, as illustrated in Fig. 14. There they form "electrodes," the name given to wires that lead current into or out of a solution.

As soon as the current is switched on, bubbles of gas are seen to rise in the two test tubes, and it is found that the quantity of gas formed at the negative pole is about twice that formed at the positive pole. The experiment is allowed to continue until the test tube over the copper wire is nearly full, and the current is then switched off and the wires are removed. Then bring the mouth of the tube containing the larger quantity of gas to the flame and the gas takes fire, burning with a blue flame. It is, in fact, hydrogen. The second of the two gases is oxygen, as the introduction of a glowing chip of wood shows.

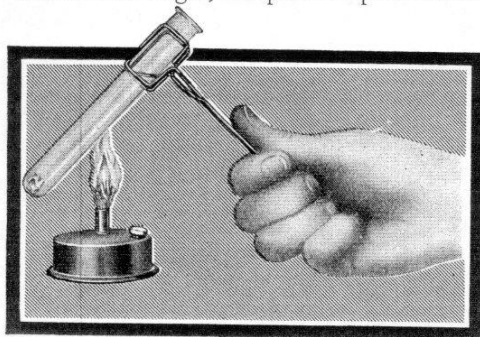


Fig. 15. Ice still unmelted in water that is heated to boiling point.

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The hydrogen and the oxygen produced in this experiment have been formed from the water, for the purpose of adding Sodium Bisulphate is to enable a current to be passed through the liquid, since water is a poor conductor. Thus water is shown to contain the two gases hydrogen and oxygen in the proportion of 2 to 1 by volume.

6. WATER, NATURE'S SOLVENT

Water is one of the most important chemicals, as well as being one of the most abundant, for it is as necessary to animal life as oxygen, and plants cannot grow without it. In nature this wonderful liquid occurs in the form of rain and in springs, rivers and oceans, but pure water is practically never met with, for the liquid is a wonderful solvent, being capable of dissolving a large number of substances. Even rain water contains dissolved carbon dioxide and other impurities derived from the air.

Pure water may be obtained by distillation, the name given to the double process of evaporation or change of liquid to vapour by heating, and condensation or the opposite change from vapour to liquid, brought about by cooling. Place the large right angle delivery tube in a small bored cork and fit this into a test tube. The delivery tube leads into a clean dry test tube, which stands in water in a basin.

Water to a depth of about an inch is placed in the first test tube, and in order to show the effect of distillation a few crystals of common salt are added. Heat the salty water to boiling. Steam passes into the dry test tube, where it is cooled and condensed. The distilled water collected in this manner

does not taste of salt, and also lacks the pleasant flavour of tap water.

Curious Properties of Water

Water is a poor conductor of heat, and a piece of ice with sufficient wire wrapped round to make it sink to the bottom of a test tube nearly full of water remains unmelted while the liquid above it is boiled (Fig. 15). Water may be heated quickly if advantage is taken of the fact that hot water is lighter than an equal bulk of cold water. If a flame is placed under a vessel containing water, the liquid heated rises, forming what is called a convection current. This explains why water in a kettle or pan must be placed above a fire instead of by its side, when the water in it is required to boil quickly.

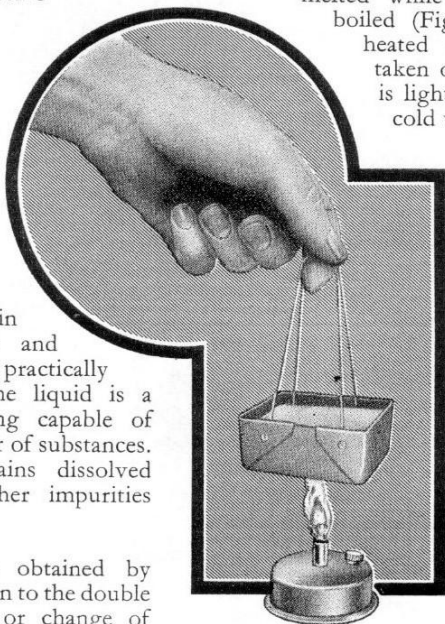


Fig. 16. Heating water in a vessel made of paper.

Convection currents carry heat away rapidly from the bottom of the vessel containing liquid. This is shown in an interesting experiment in which water is boiled in a vessel made of paper. Fold a sheet of glazed paper as shown in Fig. 16. Place water in the vessel thus formed and suspend it by means of string above the flame. The liquid becomes hot and may even boil before the paper is burned, for the heat transmitted to the paper is communicated to the water and the temperature of this cannot rise above boiling point.

How the Chemist Uses Water

To the chemist water is of great importance because so many substances dissolve in it,

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and chemical changes readily take place in solution. In order to find whether a chemical is soluble in water, place one measure of it in a test tube containing water to a depth of an inch, close the end of the test tube with the thumb, slowly invert it, and restore it to its normal position in order to mix the substance with the water. Test common salt, Lead Nitrate (No. K113) and Magnesium Sulphate (No. K117) in this manner. In each case the solid disappears from sight and therefore is soluble in water.

Add a second measure of salt to the solution already prepared and shake the tube. If the further quantity dissolves, add more. Eventually a stage is reached when the water in the tube will dissolve no more salt, and

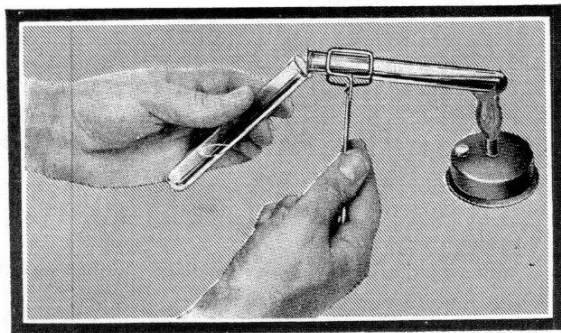


Fig. 17. Making carbon dioxide by heating an organic substance with copper oxide.

the solution is then said to be saturated. Different amounts of various soluble chemicals are required to saturate a given quantity of water. Repeat the experiment with Manganese Dioxide (No. K118). Shaking a measure of this substance with water makes no apparent difference to the quantity to be seen in the tube. Manganese Dioxide is insoluble in water.

Separating Sand from Sugar

Mix four measures of sugar with an equal quantity of sand. Half fill a test tube with water, add the mixture and shake. Then filter the liquid. Undissolved sand is left on the filter paper. Wash it free from sugar

by pouring successive small quantities of water through it, and put it in a warm place to dry. Place the filtrate in a saucer and leave this also in a warm place. The water slowly evaporates, leaving the sugar in the saucer.

This experiment shows how an insoluble substance may be separated from a soluble one. Repeat it with the residue in the test tube used in the preparation of oxygen. Unchanged Manganese Dioxide is left on the filter paper. The solution gives a white powder on evaporation. This is potassium chloride, the substance left when the Potassium Chlorate in the mixture lost oxygen.

Most chemicals are more soluble in hot water than in cold. Add one measure of common salt to the saturated solution already prepared and heat the liquid to boiling point. A little more salt dissolves.

Try the same experiment with Potassium Nitrate (No. K124). The extra measure dissolves as the temperature is raised, and further measures of Potassium Nitrate added to the hot liquid also readily dissolve. A given volume of water dissolves nearly 20 times as much Potassium Nitrate at boiling point as at freezing point.

Mysteries of Crystallisation

Allow the solution of Potassium Nitrate to cool and the extra quantity dissolved then separates out. Pour off the liquid and shake the solid on to a piece of blotting paper. Examine the residue when it is dry. It consists of a number of needle-shaped pieces that have long flat sides and are of a definite geometrical shape. These are crystals of Potassium Nitrate.

When a chemical separates from its solution in water in this manner it usually does so in the form of crystals. These vary in shape—each substance having its own

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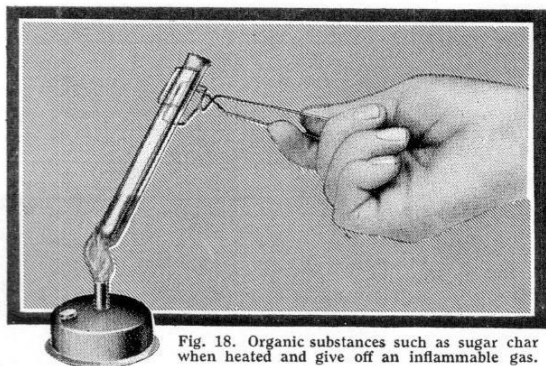


Fig. 18. Organic substances such as sugar char when heated and give off an inflammable gas.

peculiar crystalline formation—and also in size. Larger crystals are best obtained by allowing the solution from which they separate to cool slowly, and small ones are produced by rapid cooling while stirring.

Prepare crystals of Copper Sulphate (No. K108), Potassium Chlorate (No. K122), Iron Alum (No. K111), Magnesium Sulphate (No. K117), Lead Nitrate (No. K113), and other soluble chemicals contained in the Outfit. After drying them on clean blotting paper, compare their shapes, using a magnifying glass of low power if one is available.

Small Crystals Grow into Large Ones

Make sufficient saturated solution of Copper Sulphate to fill an egg cup or a similar vessel, and by means of fine thread passing over a piece of wood laid across the top of the vessel hang in the solution a well shaped crystal of Copper Sulphate obtained in one of the previous experiments. Place the vessel in a cool place where it will not be disturbed, and examine the crystal from time to time. As the solution slowly evaporates the crystal grows, but always preserves its shape, the additional material being laid down in regular layers on the existing faces.

It is interesting to grow a string of crystals of sugar in this manner. Dissolve as much moist sugar as possible in a test tube nearly

full of hot water, and place the tube in an upright position where it will not be disturbed. Tie one end of a piece of string or strong thread to a strip of wood, and place this strip across the top of the test tube with the thread, which must be nearly as long as the tube, hanging in the solution. A Meccano nut tied to the lower end of the thread will keep it in position.

Allow the solution in the tube to cool slowly. Sugar begins to crystallise on the string, and in time the small crystals grow into large ones, thus forming what is often known as sugar candy.

Many crystals contain water. There is so much water in crystals of sodium carbonate, or washing soda, that this substance dissolves in the water set free when the crystals are heated. Test this by heating a few crystals of washing soda in a dry test tube. On the other hand, common salt, Potassium Nitrate, and Potassium Chlorate contain no water of crystallisation, and crystals of these substances dried by pressing between sheets of clean blotting paper give no steam when heated in a dry test tube.

Many interesting colour changes take place when crystals lose water of crystallisation. Heat a small crystal of Copper Sulphate in a dry test tube. Water is given off, and the colour of the Copper Sulphate changes from

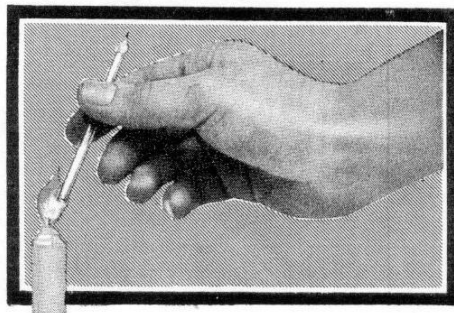


Fig. 19. Extracting unburned vapour from the interior of a candle flame.

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blue to white. Allow the tube to become cold and then add a drop of water. The white solid soaks up the liquid and then turns blue once more. Cobalt Chloride crystals show an even more interesting change when heated, the red colour changing to blue. Addition of water after cooling then restores the original red colour.

Ink for Secret Writing

Dissolve two measures of Cobalt Chloride (No. K105) in sufficient water to cover them at the bottom of a test tube. Using this solution as an ink, write on a sheet of glazed paper with a clean pen or a sharpened match stick. When the "ink" dries, the writing is practically invisible. Now hold the paper in front of a fire or over a flame, and the writing is revealed in strong blue lines. When the paper cools the colour fades away, and may be made to disappear more quickly by breathing on it.

The solution may be employed as a secret ink, for writing carried out with the pink solution is almost invisible; and cautious dilution with water gives a solution so weak that writing carried out with it would escape any but the most careful scrutiny. However dilute the solution is made, however, the writing is clearly revealed immediately on heating the paper.

Liquids such as Cobalt Chloride solution are sometimes called "sympathetic inks." There are many varieties, but not all are

as good as Cobalt Chloride, for with this substance the writing may be made to appear and disappear as often as required. The juice of a lemon or of an onion, milk and vinegar may be used as sympathetic inks in exactly

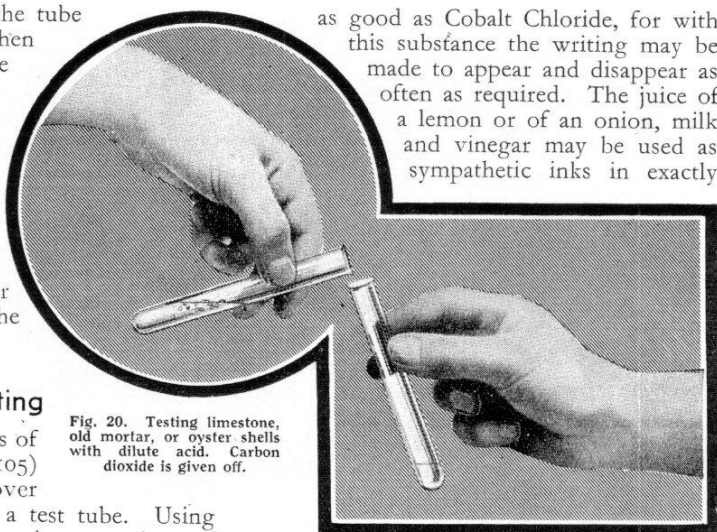


Fig. 20. Testing limestone, old mortar, or oyster shells with dilute acid. Carbon dioxide is given off.

the same manner as the Cobalt Chloride solution, but in these cases the heat of the fire reveals the writing by scorching the paper readily where it has been in contact with the sympathetic ink. The writing therefore cannot be made to disappear after it has once been brought out.

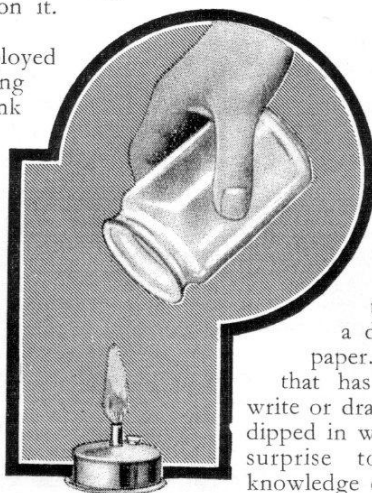


Fig. 21. Extinguishing a flame by pouring carbon dioxide over it.

Writing with Tea and Water

Mix together one measure of Tannic Acid (No. K132) and one of Iron Alum (No. K111) that has been crushed to a powder. Place the mixture on a sheet of writing paper and rub it into the paper thoroughly with the aid of a dry pad of cotton wool or paper. Shake off the powder that has not been absorbed, and write or draw on the paper with a pen dipped in water. The result is a great surprise to those who have no knowledge of chemistry, for the water acts like a black ink, producing writing that is easily readable.

The explanation of this experiment is that in solution the two chemicals form a black precipitate of iron tannate. A very good ink may be made by dissolving one measure of each in separate test tubes one quarter filled with water and mixing the solutions. A little gum should be stirred into the black liquid formed.

This chemical change enables Tannic Acid to be used as a secret ink. Make a solution of this in the manner already described, write with it on white paper and allow the writing to dry. Moisten a strip of clean blotting paper with a solution of Iron Alum of the strength already given and press this on the paper. The invisible writing immediately shows up as strongly as if freshly written with black ink.

This effective trick will mystify most observers if the writing with Tannic Acid is secretly carried out beforehand. It may be reversed, the Iron Alum solution being used as the ink and the blotting paper dipped in a solution of Tannic Acid, or even strong tea, which sometimes contains a small proportion of Tannic Acid.

7. AN ELEMENT WITH MANY DISGUISES

So far we have made experiments with three elements, oxygen, nitrogen and hydrogen. These are gases, but in combination with other elements they form solids and liquids. Now we turn to deal with a remarkable element that appears in several different forms. Its chemical name is carbon, but in its various disguises it is known to us

as diamond and graphite, and also as charcoal, lampblack, gas carbon and coke, all of which are impure forms of the element.

Thousands of carbon compounds are known, and they are grouped together as organic substances, this name having been given to them because it was formerly supposed that they could only be produced by living organisms. They include brilliantly-coloured dyestuffs, perfumes, and foodstuffs such as starch and sugar; and it seems difficult to believe that many of these contain the element most familiar to us in the form of charcoal.

A simple and conclusive proof of the presence of carbon in these and other organic materials is to obtain carbon dioxide from them by heating them with Copper Oxide. For instance, mix four measures of crushed sugar with one measure of Copper Oxide (No. K107) and heat this mixture in a small test tube held horizontally, placing a test tube containing a few drops of lime water with its mouth below that of the tube containing the mixture (Fig. 17). After

heating strongly for a few minutes shake the lime water with the gas in the test tube. The liquid turns milky, proving that the sugar contains carbon that has united with the oxygen of the Copper Oxide to form carbon dioxide. Similar tests prove the presence of the element in cheese, meat, bread and the other organic substances.

Inflammable Gases from Wood, Sugar and Paper

Heat small quantities of each of the

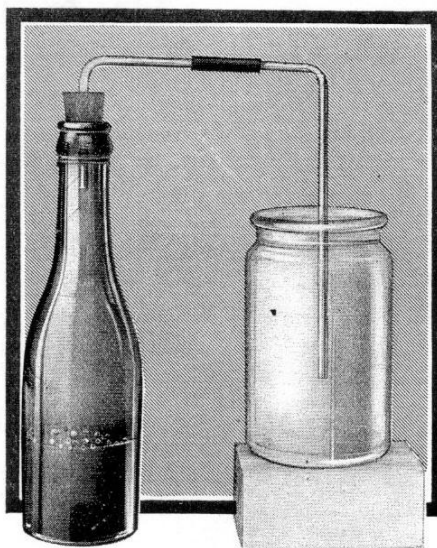


Fig. 22. Preparing carbon dioxide by the action of vinegar on washing soda.

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organic substances already mentioned in a small test tube, and ignite the gas given off by bringing the mouth of the tube to the flame of the lamp (Fig. 18). In all cases this gas burns with a yellow smoky flame, and drops of a tarry liquid collect on the inner surface of the tube. The gas and the tarry liquid are similar to the products of the heating of coal carried out in gasworks.

The smoky luminous flame of coal gas is now seldom used. Instead the gas is mixed with air before burning, the flame of the mixture being blue and not smoky. It is hollow and unburned gas can be extracted from the interior. A similar experiment can be made with the unburned vapour in the interior of a candle flame (Fig. 19).

Experiments with Carbon Dioxide

One of the most important compounds of

carbon is carbon dioxide, the heavy invisible gas we have already made by burning organic substances. It is more easily prepared by pouring vinegar on crystals of washing soda placed in a test tube. A vigorous effervescence occurs and the gas produced turns lime water milky when it is carefully poured downward into a second test tube containing this liquid (Fig. 20). Washing soda is known to chemists as sodium carbonate, and is one of the salts of carbonic acid, a weak acid formed by dissolving carbon dioxide in water.

Many other common substances are

carbonates. Test oyster shells, whiting, chalk, limestone, tooth powder, old mortar and marble by adding a little vinegar to a small quantity of each in turn, warming slightly if necessary. In all cases carbon dioxide is given off. The chalk tested must be natural chalk.

A jar of carbon dioxide may be prepared by the action of vinegar on washing soda in a small bottle fitted with a small bored cork and a delivery tube to carry the gas downward (Fig. 22). When the apparatus is ready place a tablespoonful of washing soda in the bottle, cover it with water and pour in a test

tube full of vinegar. Place the cork in the neck of the bottle immediately, and the gas given off is driven into the jar. If only one right angle delivery tube is available, this is fitted directly into the cork and the bottle is tilted to allow the delivery tube to dip into the jar in which the gas is to be collected.

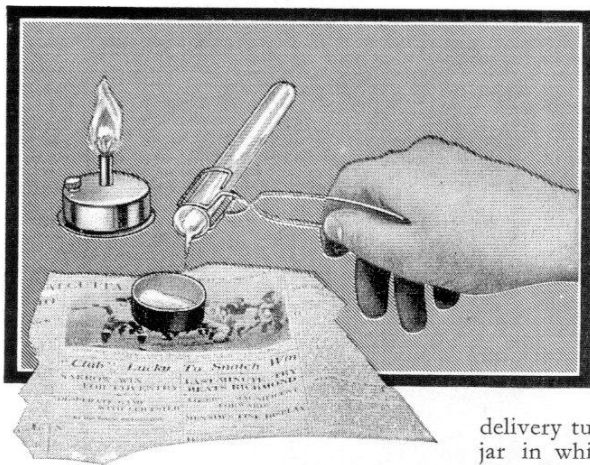


Fig. 23. Reproducing a newspaper illustration on a sulphur medallion.

Pour the carbon dioxide that has been collected in this experiment over a lighted candle or spirit lamp (Fig. 21). The flame is extinguished immediately and without the fuss that would follow the use of water for similar purposes. The gas acts by blanketing out the air and thus choking the flame, for ordinary combustibles do not burn in the gas.

Prepare and collect a second jar of carbon dioxide. Ignite one end of a piece of Magnesium Ribbon (No. K116), about 2 in. in length, held in a pair of tongs or pliers, and lower the burning end quickly into the jar. The metal continues to burn with a brilliant flame and its white ash is mixed

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with black specks of carbon. The explanation of this is that although a candle or a wood splint does not burn in carbon dioxide, burning magnesium is not extinguished by the gas because this metal has a greater attraction than carbon for oxygen. It robs the carbon of its oxygen, therefore, to form the white ash we know to be magnesium oxide, turning the element out of the invisible gas. In this experiment the carbon is liberated in the form of a fine black powder.

Curious Effect of Carbon Dioxide on Lime Water

Changes of an interesting kind occur when carbon dioxide is passed through lime water contained in a test tube. The solution first turns milky, but as we already know, becomes clear when more carbon dioxide is passed through. Boil the clear liquid and once more it becomes milky, bubbles of carbon dioxide being given off.

The first action of the carbon dioxide on the lime is to form calcium carbonate, which is a white substance insoluble in water. On continuing to pass carbon dioxide calcium bicarbonate is formed, and as this is soluble in water the solution becomes clear once more. Finally, boiling the solution of calcium bicarbonate causes this substance to decompose, calcium carbonate being reformed with the loss of carbon dioxide, and thus the solution again becomes milky.

A similar series of changes are brought about by breathing through a tube dipping into lime water, but this may take a little

longer owing to the small proportion of carbon dioxide in the breath.

8. NITROGEN—A SLUGGISH ELEMENT

Our experiments have shown that about four-fifths of the atmosphere consists of nitrogen, a colourless gas that prevents burning, breathing and other changes in which the air takes part, from proceeding too quickly. Nitrogen does not seem eager to unite with other elements, but although sluggish and lazy, it forms part of many complex chemicals that are present in plants and in animals. Life indeed would be practically impossible without it, and it must be present in a certain proportion in the food of both plants and animals.

In order to show the presence of nitrogen in a substance of animal origin add three measures of Calcium Oxide (No. K103) and a few drops of water to a small quantity of wool in a test tube. Place a piece of moist red Litmus paper over the mouth of the tube and heat the mixture

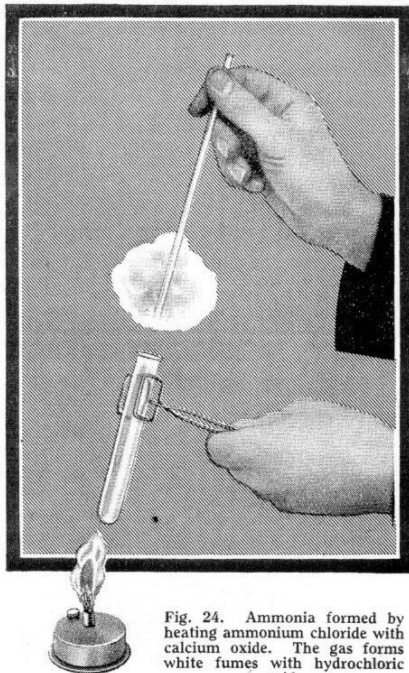


Fig. 24. Ammonia formed by heating ammonium chloride with calcium oxide. The gas forms white fumes with hydrochloric acid.

gently. The Litmus paper becomes blue, and on cautiously smelling the vapours given off the odour of ammonia is recognised. Ammonia is a compound of nitrogen, and its production in this experiment is a proof of the presence of the element in wool. Make similar tests with hair and cheese.

Ammonia is a gas and is more easily prepared by heating one measure of Ammonium Chloride (No. K101) with one

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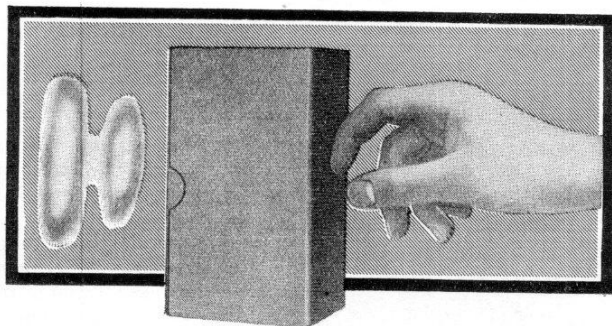


Fig. 25. Vortex rings of the fumes formed by ammonia and hydrochloric acid.

measure of Calcium Oxide (No. KI03). The smell of ammonia is detected immediately on mixing the two chemicals, and gentle warming produces the gas in greater quantity. Dip the end of a clean glass rod into dilute hydrochloric acid and hold it near the open end of the test tube in which ammonia is being produced. Thick white clouds are immediately formed by the combination of the ammonia with the hydrochloric acid to form ammonium chloride (Fig. 24).

Ammonium Chloride Smoke Rings

An interesting experiment with clouds of ammonium chloride may be carried out with the aid of the box illustrated in Fig. 25. This is made by cutting a small hole about $\frac{1}{2}$ in. in diameter in the centre of the base of a small cardboard box, and a rectangular opening in the lid, this opening being nearly as large as the box itself. Over the rectangular opening gum a sheet of parchment paper to replace the cardboard cut out.

Stand the box on end with shallow saucers or dishes containing warm household ammonia and hydrochloric acid respectively inside it. Thick clouds of ammonium chloride are formed and on smartly tapping the parchment cover rings of smoke are shot out of the circular hole in the base. These are known as vortex rings and it is interesting to see the smoke composing them

whirling round as the rings drift away from the box. Smaller rings may be obtained by pasting paper or thin card over the hole and cutting out a new opening of smaller diameter.

Making Ammonia Solution

Place a mixture of five measures each of Ammonium Chloride (No. KI01) and Calcium Oxide (No. KI03) in a dry test tube fitted with a small bored cork and the large right angle delivery tube. Hold the test tube in a horizontal position over the flame, with the delivery tube pointing upward into an inverted dry test tube. The ammonia given off collects in this tube, for it is lighter than air. When the tube seems to be full of the gas, place its mouth under water, still in an inverted position. When a little water has entered close the test tube with the thumb and shake the ammonia with the water. The gas dissolves, giving an alkaline liquid.

More ammonia solution may be prepared by turning the delivery tube downward to dip just below the surface of water to the depth of an inch in a test tube (Fig. 26). The delivery tube must be lifted out as soon as the stream of bubbles of gas ceases

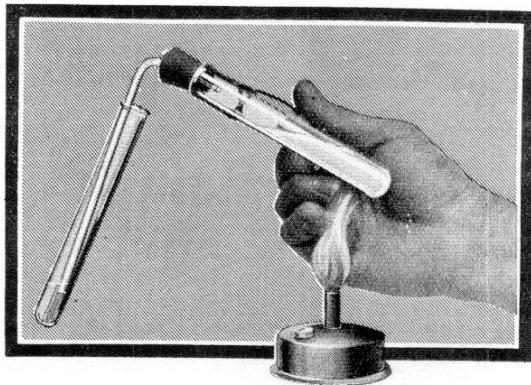


Fig. 26. Passing ammonia gas into water in order to form a solution.

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in order to prevent water entering the test tube in which the mixture is being heated.

The ammonia solution thus prepared is similar to that sold in shops and used for household purposes. It has the same smell, and a Litmus paper dipped into it turns blue. Chemically it is ammonium hydroxide, formed by the union of ammonia with water, but splits up on warming, ammonia gas being given off.

9. SULPHUR—THE VOLCANIC ELEMENT

Sulphur or brimstone is one of the most interesting of the elements. Its second name means the burning stone, and it is found in the craters of volcanoes. The gases rising from a volcano in eruption contain fumes of burning sulphur, and this fact, together with the ease with which the element takes fire, the deadly pallor of its pale blue flame, and the choking smell of the fumes produced have given sulphur sinister associations as the chief ingredient of supernatural fires. In reality it is a very useful element, and is employed in making matches and gunpowder, and in the rubber and other industries.

How Sulphur Disguises Itself

Sulphur is a yellow solid but readily melts when heated and the liquid boils at a temperature of 450°C . Like carbon it is capable of assuming disguises and some of the different forms it takes are best made by heating it. Place six measures of Sulphur (No. K131) in a small dry test tube and heat

slowly. The element melts to form a pale yellow mobile liquid, and on further heating becomes darker and darker in colour until eventually it is a deep reddish brown. At this stage it is syrupy, and does not fall out even when the tube is inverted. Continue to heat, and the liquid, still dark red in colour, again becomes mobile. Pour it into water in a saucer. Note that during the experiment part of the Sulphur has been changed into a vapour which has cooled in the upper part of the test tube on the sides of which a pale yellow powder is visible.

The form of sulphur obtained by pouring the very hot liquid into water is very curious, for it may be pulled and stretched like a

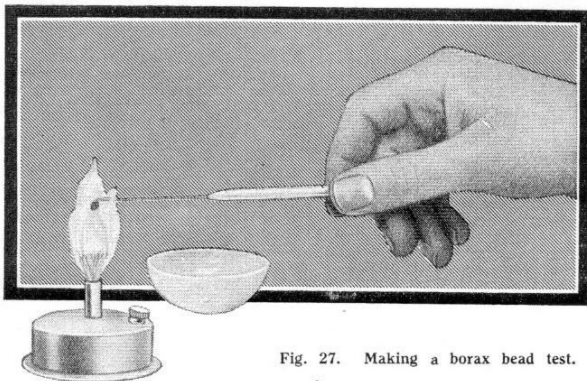


Fig. 27. Making a borax bead test.

piece of indiarubber. It loses its elasticity in a few hours, changing automatically into a hard brittle mass that is seen to consist of tiny eight-sided crystals which are readily seen by means of a powerful

magnifying glass or microscope.

A Novel Printing Process

An interesting experiment with sulphur is in reproducing pictures and type from newspapers, for in certain conditions printers' ink adheres to it readily. Surround the portion of a picture that is to be reproduced with a ring of cardboard, which is best obtained by removing the bottom from a small cardboard box. Heat sulphur in a dry test tube until a pale yellow liquid is obtained, and pour this into a mould (Fig. 23). On cooling remove the cardboard, and the picture will be found to be transferred to the lower side of the Sulphur medallion formed within it. The picture is, of course,

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reversed but otherwise is a replica of the illustration from which it was reproduced.

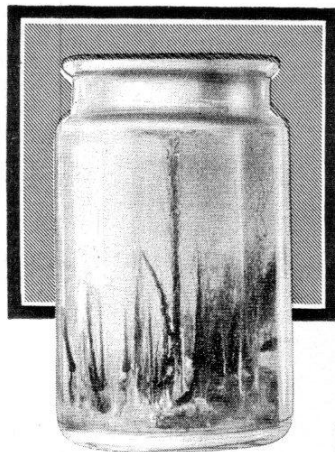


Fig. 28. A chemical garden in which the "plants" have grown from crystals of magnesium sulphate and other chemicals.

Burn one measure of Sulphur (No. KI31) on an old spoon and cautiously smell the gas formed. The gas is sulphur dioxide, and its peculiar choking smell enables it to be recognised easily.

Sulphur combines readily with certain metals when heated with them. Iron is one of these. Place four measures of Iron Filings (No. KI12) contained in the Outfit in a small tin lid, and hold this in a pair of tongs over a glowing fire for a few minutes. Then lift the tin lid off the coals, and sprinkle over it in successive small quantities four measures of Sulphur (No. KI31). Part of the sulphur burns with an intense blue flame, but the rest melts and combines with the Iron Filings to form iron sulphide. Reheat the Iron Filings at intervals during this experiment, and finally hold the tin lid on the fire until no more blue flames are seen, showing that the excess of sulphur has been burned away. The black residue is iron sulphide, formed by the direct union of the metal with sulphur.

Allow the tin lid and its contents to cool and then place one measure of the black residue in a test tube, cover with one measure of Sodium Bisulphate (No. KI25) and add a few drops of water. A gas having the unpleasant smell associated with bad eggs is given off. This is sulphuretted hydrogen.

The smell of sulphuretted hydrogen usually is a sufficient proof of its presence, but a strip of blotting paper that has been dipped in a solution of one measure of Lead Nitrate (No. KI13) in a test tube half filled with water may be used to detect small quantities of the gas. Hold this in the tube in which Sodium Bisulphate has been added to the iron sulphide prepared in the last experiment, and it immediately becomes coated with a black stain of lead sulphide, which has a peculiar metallic glitter.

10. INTERESTING ANALYTICAL TESTS

Borax is a chemical of special interest because of its use by analysts, who make with it what are usually described as borax bead tests. The beads are made in a loop at the end of the Nickel Chrome Wire (Part No. K39) fixed into a short piece of glass tube that serves as a handle. One end of the glass tube is drawn out to a jet. The end of the wire is placed just within the jet, which is then heated until it softens and closes round the wire. On cooling this is firmly held in position, projecting from the glass tubing as a knife blade does from its haft. An alternative is to bind the wire by means of thread to a short piece of wood that serves as a handle.



Fig. 29. Cobalt chloride growths in a chemical garden.

Twist the end of the wire into a loop about $\frac{1}{4}$ in. in diameter. Heat the loop in the flame and dip it into a small quantity of borax, placed on a sheet

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of paper in a convenient position. The borax adheres to the loop, and on heating first swells up as it loses water of crystallisation, and then melts down to form a clear glass bead within the loop (Fig. 27). It may be necessary to dip the wire into borax a second time in order to obtain a good bead, and the heating must be continued until a clear colourless glass bead is obtained.

Touch a minute crystal of Cobalt Chloride (No. K105) with the hot bead and reheat. The bead becomes deep blue in colour owing to the formation of blue cobalt borate. The colour is best seen on using only a very minute quantity of Cobalt Chloride.

Copper, iron and manganese compounds give greenish blue, yellow and pale rose beads respectively.

11. CHEMICAL GARDENS

Melting compounds of metals with sand gives rise to silicates. The simplest silicate is that of sodium and is formed by melting clean sand with sodium carbonate. It is well known under the name of water-glass, a name given to it because it dissolves in water to form a thick glassy-looking syrup.

The silicates of most metals are insoluble, and a fascinating way of preparing them is to drop crystals of their soluble salts into a solution of water-glass. For this purpose prepare sufficient solution of water-glass to fill a large glass jar, using the syrup in the proportion of one tablespoonful to a tumblerful of water. Place the jar in a position in which it will not be disturbed, and drop into the solution two or three small crystals of Cobalt Chloride (No. K105). A slender column of cobalt silicate then grows on each crystal. Usually a small bubble may be seen at the top of each rising

column, and in a few hours the growth becomes wider and taller until it reaches the surface of the solution.

Other chemicals give rise to growths of this kind, and Figs. 28 and 29 show "chemical gardens" produced by "planting" Copper Sulphate (No. K108), Magnesium Sulphate (No. K117) and other chemicals in addition to Cobalt Chloride.

Fascinating Diffusion Experiments

Interesting experiments in diffusion may be carried out with the aid of one of the round cardboard boxes used for holding cheese. Cut out the disc portion of both the box and the lid. Stand the cardboard ring thus obtained from the box upside down, and place on it a circular sheet of parchment, or parchment paper, about an inch larger all round. Then put on the remains of the lid so as to hold the paper in position. This gives a shallow drum that can be floated on water in a basin (Fig. 30).



Fig. 30. Separating sugar from starch by slow diffusion taking place through parchment.

Sugar and salt slowly diffuse through the parchment when solutions of these chemicals are placed in the drum, and their presence in the outer liquid may be shown by tasting. There are substances that do not pass through a membrane of this kind, however. Starch is one of these. Mix half a teaspoonful of starch into a smooth paste with water in a cup and then fill the cup with boiling water, stirring meanwhile. Add enough sugar to make the liquid noticeably sweet, and after cooling pour some of it into the drum and float this on water. Sugar may be detected in the outer liquid a few hours later, but the liquid does not give a blue colour when a drop of tincture of iodine is added. This is a proof that no starch has passed through the parchment.

KEMEX

List of Parts and Contents of Outfits

No.	Description	Quantities in Outfits			No.	Description	Quantities in Outfits		
		No. 1	No. 2	No. 3			No. 1	No. 2	No. 3
K1	Test Tube, 5" x 1/2"	4	4	6	K40	Instruction Manual, No. 1	1	—	—
K2	" " Heat Resisting, 4" x 1/2"	—	2	2	K41	" " " No. 2-3	—	1	1
K3	" " Stand	—	1	1	K42	Universal Stand, Wing Screw	—	—	—
K4	" " Holder	1	1	1	K100	Aluminium Sulphate	—	—	1
K5	" " Brush	1	1	1	K101	Ammonium Chloride	1	1	1
K6	Funnel	1	1	1	K102	Calcium Carbonate (Marble)	—	—	1
K7	Filter Paper, 3 1/4" diameter	12	50	100	K103	Calcium Oxide (Lime)	1	1	1
K8	Evaporating Dish	—	1	1	K104	Charcoal	—	—	1
K9	Gauze Square	—	1	1	K105	Cobalt Chloride	1	1	1
K10	Flask, Wide-necked	—	—	1	K106	Congo Red	—	—	1
K11	Thistle Funnel	—	1	1	K107	Copper Oxide	1	1	1
K12	Right Angle Delivery Tube, Small	—	1	1	K108	Copper Sulphate	1	1	1
K13	" " " Large	1	1	1	K109	Copper Turnings	—	—	1
K14	Double Angle Delivery Tube	1	1	1	K110	Ferrous Ammonium Sulphate	—	—	1
K15	Glass Tube, 12"	—	—	2	K111	Iron Alum	1	1	1
K16	" Rod	1	1	1	K112	Iron Filings	1	1	1
K17	Cork, Large, Double Bore	—	—	1	K113	Lead Nitrate	1	1	1
K18	" Small	—	1	4	K114	Litmus	1	1	1
K19	" " Bored	2	3	4	K115	Logwood	1	1	1
K20	Blowpipe	—	—	1	K116	Magnesium Ribbon	1	1	1
K21	Charcoal Block	—	—	1	K117	Magnesium Sulphate	1	1	1
K22	Spirit Lamp, Complete	1	1	1	K118	Manganese Dioxide	1	1	1
K23	" " Stopper	—	—	—	K119	Manganese Sulphate	—	—	1
K24	" " Wick Holder	—	—	—	K120	Nickel Ammonium Sulphate	—	—	1
K25	" " Wick	—	—	—	K121	Phenolphthalein Solution	—	1	1
K26	Universal Stand, Complete	—	—	1	K122	Potassium Chlorate	1	1	1
K27	" " Base	—	—	—	K123	Potassium Iodide Solution	—	—	1
K28	" " Pillar	—	—	—	K124	Potassium Nitrate	1	1	1
K29	" " Ring	—	—	—	K125	Sodium Bisulphate	1	1	1
K30	" " Pillar Extension	—	—	—	K126	Sodium Bisulphite	—	—	1
K31	" " Clamp	—	—	—	K127	Sodium Borate (Borax)	—	—	1
K32	" " Top Bracket	—	—	—	K128	Sodium Ferrocyanide	—	—	1
K33	" " Wing Nut	—	—	—	K129	Sodium Thiocyanate	—	—	1
K34	" " Washer	—	—	—	K130	Strontium Nitrate	—	1	1
K35	Evaporating Stand	—	1	—	K131	Sulphur	1	1	1
K36	Scoop	1	1	1	K132	Tannic Acid (Tannin)	1	1	1
K37	Rubber Connection Tube	1	1	1	K133	Tartaric Acid	—	1	1
K38	Asbestos Fibre	1	1	1	K134	Zinc, Granulated	1	1	1
K39	Nickel Chrome Wire	1	1	1					

HOW TO CONTINUE

Now that you have experienced the fun and excitement of carrying out chemical experiments you will be keen on proceeding further with this wonderful hobby. You may do this by purchasing a No. 2 or No. 3 Kemex Outfit, either of which will enable you to perform a splendid series of entirely new experiments.

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